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Impacts of Manwan Dam construction on aquatic habitat and community in Middle Reach of Lancang River

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Abstract

Aquatic habitats have been affected worldwide by dams for hydroelectric generation, resulting in biological impactts. Great changes in Manwan Reservoir area had been taken place on aquatic habitat in pre-and post-dam periods. The storage resulted in area increase of water body from other habitats. The flow at Gajiu hydrological station gave rise to divergent oscillation in dry season and changed smoothly in wet season after the completion of dam, respectively. Besides, months of maximum discharge also was found to be oscillatory during construction period. Surface water temperature, ammonia nitrogen (NH_3-N) and total phosphorus (TP) content were higher in pre-dam period than that in post-dam period. The variation of habitats led to number increase and structure change of species, includeing algae, zooplankton, fishes, plant, birds and mammals. Dramatic growth of chlorophyta and appearance of euglenaphyta were associated with higher surface water temperature and NH_3-N and TP content. The change of aquatic habitat and introduction of alien fishes, such as *neosalanx taihuensis*, *tilapia nilotica*, *carassius auratus* and so on, influenced fish assemblage composition in reservoir. Despite disappearance of some shrub species, such as *homonoia riparia* and *syzygium fluviatilis*, the number of plant species also was higher in post-dam period because of the flood with herbs from mountain ridge or tributaries.

Keywords: Manwan Hydropower dam ; Habitat Species ; Flow regime ; Water quality; Surface water quality

1 Introduction

Building dams for hydroelectric generation, irrigation and flood control has been a common phenomenon worldwide for centuries [1].By 2000, the number of large dams had climbed to more than 47,000, and an additional 800,000 smaller dams now block the flow of the world's rivers [2]. Globally, over half (172 out of 292) of river sys-

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tems were influenced by dams [3]. In China (excluding Hong Kong, Macao and Taiwan), 87,085 dams were constructed until 2008[4].

Dams and reservoirs affect ecological environment through challenging both the territorial habitats of , including habitat area decrease and alteration of habitats' spatial configuration [5,6] and aquatic habitat, including hydrological intervention [7, 8], surface water temperature[9] and water quality change[10]. Biology in rivers dams have evolved and survived in the habitat that were formed long time ago before dam construction. Finally, species adapted the habitats and kept dynastical balance with these. Dams across rivers create barriers of natural water flow and interfere with the ecological processes of reservoir area. Clearly, the dam construction can affect the biological communities by changing aquatic habitats. The living organisms in aquatic ecosystems have the potential to adapt the habitat changes and keep dynastical balance with the changes.

Aquatic biology have evolved their living strategies primarily in direct response to the natural flow regimes [11] and hydrological regimes which play a major role in determining the biotic composition, structure, and function of aquatic, wetland, and riparian ecosystems [7]. Assemblages of fishes are associated with environmental variables, including flow regime and water temperature [12].Water quality, especially inorganic nitrogen and phosphorus, can affect the growth of algae [13].

In this study, we surveyed changes of aquatic habitats and living organisms between pre- and post-pre-dam periods in Manwan area, the middle reach of Lancang River to address whether the aquatic habitats varied obviously with dam construction and biological response to the changing habitats between pre- and post- dam periods in reservoir area.

2 Materials and Methods

2.1 Study area

Manwan Hydropower Dam is, located in the middle-reach of Lancang River, constructed during the period 1985 - 1998 and commissioned in 1993. The Dam is 418m long, 132m high with a storage capacity of 10.6×10^8 m^3. The normal water level is 944.0m. Water area of the dam reservoir is 23.6km^2, with the electricity generation capacity of 150×10^6 kW. The distance of backwater in main stream is about 70 km [6].

The reservoir area is located between latitude 24°25-24°40′N and longitude 100°05-100°25′E, covering the watershed of middle-reach of Lancang River in southwest, i.e., Wuliang mountain's ridge in Nanjian and Jingdong country and Luoxia river watershed in Yun and Fengqing county in north, with an area of 809 km^2[14] . The reservoir is situated in deep valleys and the Indian monsoon climate zone with the mean annual temperature of 18-20℃ and with the mean annual precipitation of 1000-1150mm [15].Division of dry season and wet season was obvious. Dry season was from November to April, and wet season was from May to October [16].

2.2 Date collection

We classified habitat in reservoir area into five types, including water body, forest, shrub, cultivated land and others (construction land and unused land). These coincided with the land use/cover types which were classified by Zhou *et al* (2008) by supervised classification with LADSAT TM images in 1991 and 2001.

We used records of river discharge (total monthly flow) from Gajiu hydrological station to summarize monthly discharge in dry season (April) and wet season (July) for periods of record before and after Manwan Dam construction (Fig1 and 2). To evaluate the effect of Manwan Dam on peak flows, we compared the differences in months of maximum discharge during pre-dam period and post-dam period (Fig.3). We also focus on the variation of surface water temperature and water quality in Manwan monitor station from pre-dam to post-dam period, and collected relevant disposal data from literatures (Fig.4). Species compositions in aquatic ecosystems in reservoir area before and after dam construction were summarized by referring to Zhang's (2001) report in order to illustrate the impact of Manwan Dam on aquatic biology (Fig.5).

3 Results

3.1 Variation of aquatic habitat

3. 1. 1 Aquatic habitat area

The area of aquatic habitat increase with 1384.56 km^2, from 552.69 km^2 in 1991 to 1937.25 km^2 in 2001, which was the result of the land transformation from forest, shrub, cultivated land and others since , the inundation of reservoir storage in 1993.

3.1.2 Flow regime

Great variations of releases from Manwan Dam in different years were associated with the great difference of the historical flows in middle reach of Lancang River. Fig.1 and 2 show the hydrological condition of dry season and wet season in pre- and post- dam periods (1980-1992 and 1993-2000), respectively. A substantial discharge was maintained throughout the dry season whereas this period was associated with lower flows than in the wet season. The flow regime from post-dam period gave rise to divergent oscillation in dry season (Fig.1). The sudden rise and fall in discharge from the pre-dam period had been replaced by smooth change in flow as large volumes of water were stored in the reservoir and released from dam by flow regulation (Fig.2).

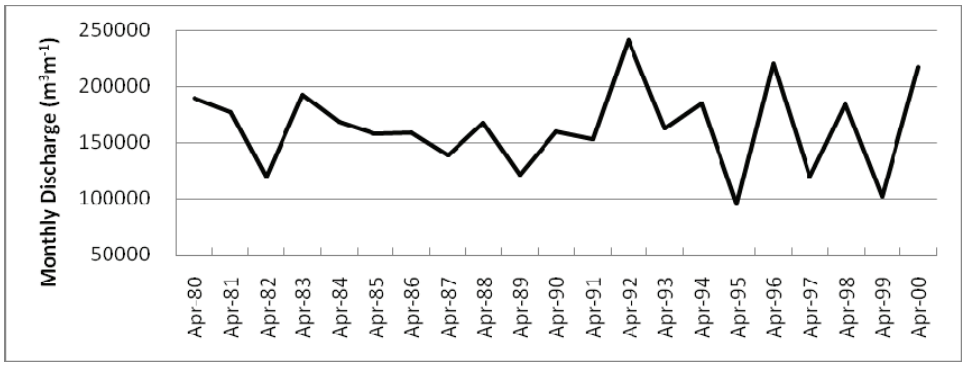


Fig.1 Monthly discharge of the Lancang River observed at Gajiu Hydrological Station: April 1980- April 2000

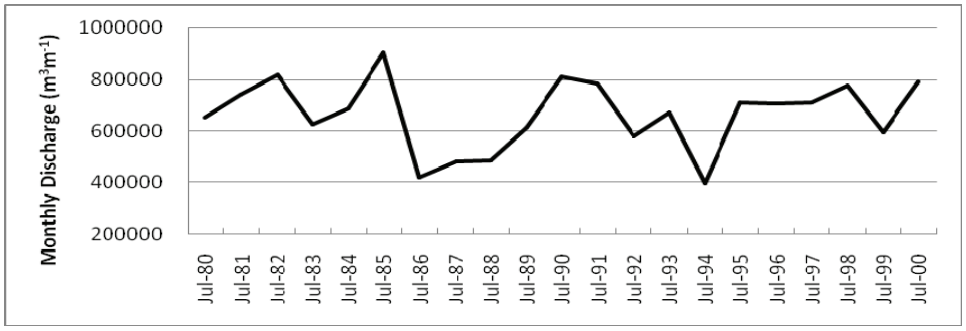


Fig.2 Monthly discharge of the Lancang River observed at Gajiu Hydrological Station: July1980- July 2000

Great change in months of maximum discharge was observed during the study period (Fig.3). Among the different periods the months of maximum discharge was found to be oscillatory during dam construction (1986-1993), compared to before dam construction (1980-1985) and after dam construction (1993-2000) when the months of maximum discharge were in July or August.

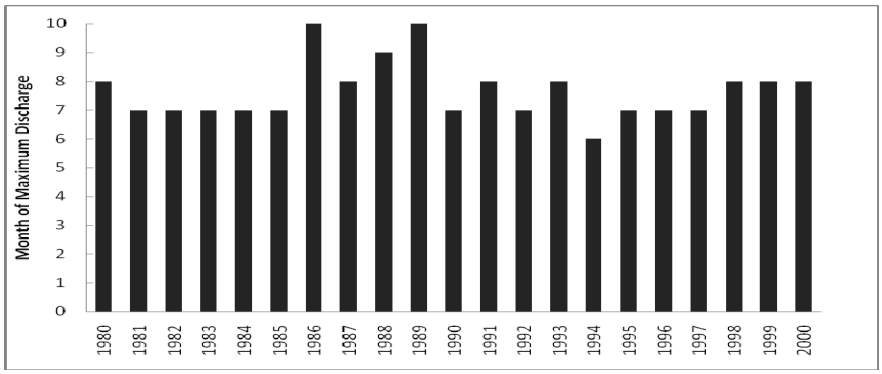


Fig.3 Months of maximum discharge of the Lancang River observed at Gajiu Hydrological Station: July1980- July 2000

3.1.3 Surface water temperature

Surface water temperature of Manwan in post-dam period (1993-2004) follows a bell-shaped trend similar to that of pre-dam period (1978-1992). The lowest and highest values of surface water temperature appeared in January and August, respectively. However, temperature in every month was much higher in post-dam period than in pre-dam period due to the transformation from river to reservoir, so the average temperature in post-dam period was 21.1℃, 4.8℃ higher than that in pre-dam period. The largest difference of temperature between pre- and post-dam was 6.7℃in November (Fig.4a).

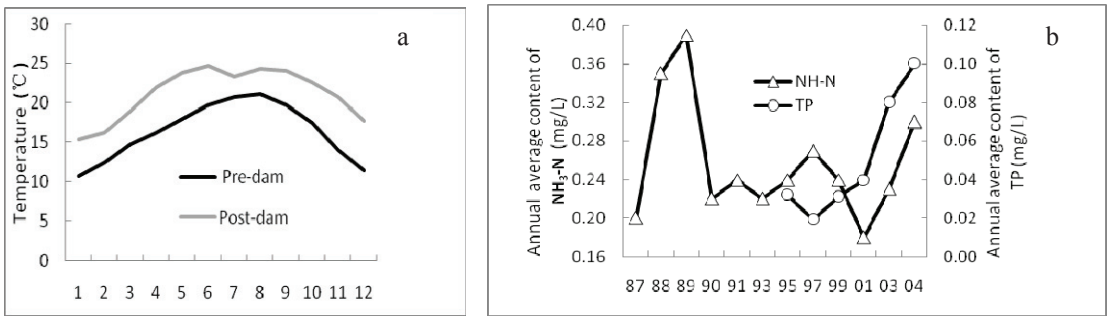


Fig.4 (a) Surface water temperature of Manwan transect in pre- and post-dam period; (b) Annual average content of NH_3-N and TP in Manwan area (Date from Yao *et al*, 2005)

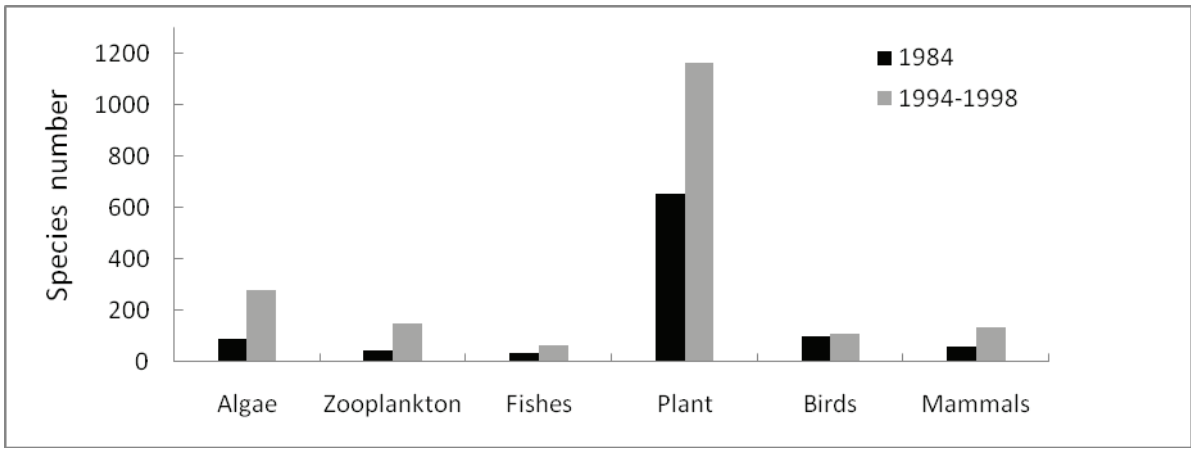
3.1.4 Water quality

There is a large amount of variation between pre- and post- periods in annual average ammonia nitrogen (NH_3-N) and total phosphorus (TP) content (Fig. 4b). Although the maximum value of NH_3-N was 0.39 mg/L in 1989, the NH_3-N content in pre-dam period (1987-1992) was lower than in post-dam period (1993-2004) and increased sharply since 2001 due to inundated plant decomposition, release from soil, sewage discharge and cumulative effect of dam. The TP content also showed a trend of increase dramatically from o.032 mg/L to 0.10 mg/L in post-dam period (1995-2004) although the data of pre-dam period was missing.

3.2 Biological effect

There are great differences in species composition between pre- versus post-dam period in Manwan area (Fig.5). The change of flow regime, combined with the change of surface water temperature and water quality after Manwan hydrological dam construction resulted in higher species number of algae and zooplankton, which had increased by 192 and 101, respectively. The species number of chlorophyta increased so dramatically that the difference of species number between chlorophyta and bacillarophyta was only two in spite of dominant species which was bacill-

arophyta. Meanwhile, twenty-one kinds of euglenophyta appeared in the reservoir (Table 1). Due to the development of aquaculture the species number of fishes had increased by 27, including 15 native species (Table 1) and 12 kinds of alien fishes, such as *neosalanx taihuensis*, *tilapia nilotica*, *carassius auratus* and so on. It was increasingly clear that plant species in 1994-1998 was twice more than those in 1994, as the flood carried herbs from mountain ridge or tributaries. The variation of land-use, especially the expansion of water body area, promoted the increase of birds and mammals.



(Data from Zhang *et al*, 2001)

Fig.5 Species composition between 1984 and 1994-1998 in Manwan reservoir

Table1. The species composition of algae and native fishes between 1984 and 1994-1998 in Manwan reservoir

Algae Species	Year		Native Fishes Species	Year	
	1984	1994-1998		1984	1994-1998
Bacillarophyta	56	100	Cypriniformes	25	36
Chlorophyta	17	98	Silutiformes	9	12
Cyanophyta	10	38	Perciformes	1	2
Euglenophyta	0	21	Mastacembelidae	1	0
Others	5	23	Cyprinodontiformes	0	1
Total	88	280	Total	37	52

4 Discussions

The growth of chlorophyta is associated with flow [17, 18], temperature [19], inorganic nitrogen and phosphorus [19, 20] . Flow is diverted into storage in the reservoir and dams cause the backwater, which result in decrease of flow. Slow flow is beneficial to the growth of chlorophyta[17]. Besides, flow is an important factor to cumulate nitrogen and phosphorus. The increase of annual average content of NH_3-N and TP in post-dam period was that inundated plant is decomposed and indisposed domestic, agricultural and industrial sewage discharge into Lancang River. The richness in N and P chemistry of rivers accelerates chlorophyta growth and eutrophication[20].The optimistic condition for euglenophyta growth is abundance of organic matter, still water body and 20-35℃ of water temperature[21], which can account for the appearance of englenophyta in post-dam period.

Fish species composition and number is related to aquatic habitat [22-24]. The ratio of dominant species, Cypriniformes and silutiformes, in biotic community is up to 91.9% in 1984 and 92.3% in 1994-1998, respectively, and the fishes adapting high or median flow always dominate in the community [22](Table 1). It is increasingly clear that low flow and static water in the reservoir has been accompanied dam construction. Streamflow strongly influences fish assemblage composition, particularly at the middle or lower flows [23]. The abundance of some juvenile fish also is positively correlated with shallow-slow habitat in summer [24]. As a result, fish species composition may take great change in the reservoir. Besides, flow disturbance and water temperature increase provide the stimulus for the intro-

duction of alien fishes in order to develop fishery industry, such as *neosalanx taihuensis*, *tilapia nilotica*, *carassius-auratus*[12]. The competitions between native and alien species change the fish community composition.

5 conclusions

Manwan Dams across Lancang River changed habitat of landscape and interfered with aquatic habitat, including flow regime, surface water temperature and water quality that could influence species number and composition. The cover area of water body increasing was converted from the reduction of forest, shrub, cultivated land and other habitats. Discharge between pre-dam period and post-dam period had a great variation in dry season and wet season. The months of maximum discharge gave rise to oscillatory during construction period (1986-1993). The variation of surface water temperature and NH_3-N and TP content in pre- and post-dam periods accelerated chlorophyta number and euglenophyta appearance. The slowing down of flow and introduction of *neosalanx taihuensis*, *tilapia nilotica*, *carassius auratus* will change fish species number and composition.

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